936 Clayton, E.E. & Gaines, T.G.

BLUE MOLD
(DOWNY MILDEW)
Disease of Tobacco

IMPERIAL MYCOLOGICAL INSTITUTE
20 JUNE 1938

FARMERS' BULLETIN No. 1799
U. S. DEPARTMENT OF AGRICULTURE

BLUE MOLD is a destructive tobacco seedbed disease throughout the area from Pennsylvania to Florida. Losses depend on weather conditions. Disastrous epidemics occurred in 1932 and 1937.

The disease is caused by a fungus (*Peronospora tabacina*), which attacks and destroys the leaves. Usually diseased plants throw out new leaves and recover, but under some conditions large numbers may be killed, particularly if the plants are infected when they are very young.

The disease is favored by cloudy weather and temperatures between 50° and 70° F. Destructive epidemics have occurred in years when warm winters were followed by very early disease appearance.

Results from studies on control measures are as follows:

(1) Cultural practices: Growers have materially reduced blue mold damage by enlarging their seedbed areas and delaying transplanting until recovery has occurred. However, if the disease attack is severe these measures may not be adequate.

(2) Heat treatment: Raising the night temperature to between 70° and 90° F. will control the disease effectively, but at present this method is not considered practical.

(3) Gas treatment: Benzol is placed in evaporating pans scattered throughout the seedbed, and the fumes are held in by means of muslin cloth or other tight covers. This method is effective but costly.

(4) Spray treatment: The spray used is a mixture of red copper oxide and cottonseed oil, and on an average, 8 to 12 applications are required. This method is not as completely effective as the gas treatment, but it is inexpensive.

Washington, D. C. Issued January 1938

BLUE MOLD (DOWNY MILDEW) DISEASE OF TOBACCO

By E. E. Clayton, *senior pathologist*, and J. G. Gaines, *assistant pathologist*, *Division of Tobacco and Plant Nutrition, Bureau of Plant Industry*

CONTENTS

	Page		Page
Introduction	1	Control measures	7
The disease	1	Cultural practices	7
Symptoms	1	Heat treatments	8
Life history of the disease	3	Gas treatment	9
Relation of weather conditions	4	Spraying	10
Host plants	5		
Losses from blue mold	6		

INTRODUCTION

BLUE MOLD is probably a native North American disease which occurs generally on wild tobaccos in the West. Apparently because commercial tobacco culture in the United States has been centered in the East, where no native tobaccos occur, our growers were not troubled by this disease until it appeared in Florida in 1921. Surprisingly, it disappeared, and was not seen again until 1931. The disease is now well established and has occurred since 1931 throughout the area from Florida to Pennsylvania. Each year the mold has first appeared between December and March in or near Berrien County, Ga.; from there it apparently spreads southward into Florida and then develops to the north as the season advances. In 1937 the disease also occurred in Tennessee, Kentucky, Indiana, Ohio, and Connecticut, but so far it has not been a serious problem in any of these States. It is a seedbed disease, and the occasional early season field infections have been of no consequence. Work on control measures was initiated in 1932 and has been continued without interruption. This work is still in progress, and material improvements in control methods may be expected in the future. However, 1937 provided a severe test for the control measures that had been developed, and the results obtained show conclusively that this disease can be controlled, even under the destructive conditions that prevailed in Georgia in 1937. Furthermore, this can be done at very moderate cost. The information here presented applies particularly to the flue-cured tobacco region.

THE DISEASE

SYMPTOMS

The usual first indication of blue mold in a bed is the appearance of one or more circular patches of yellowed leaves. Careful examination in the center of such a patch will show a few leaves with the

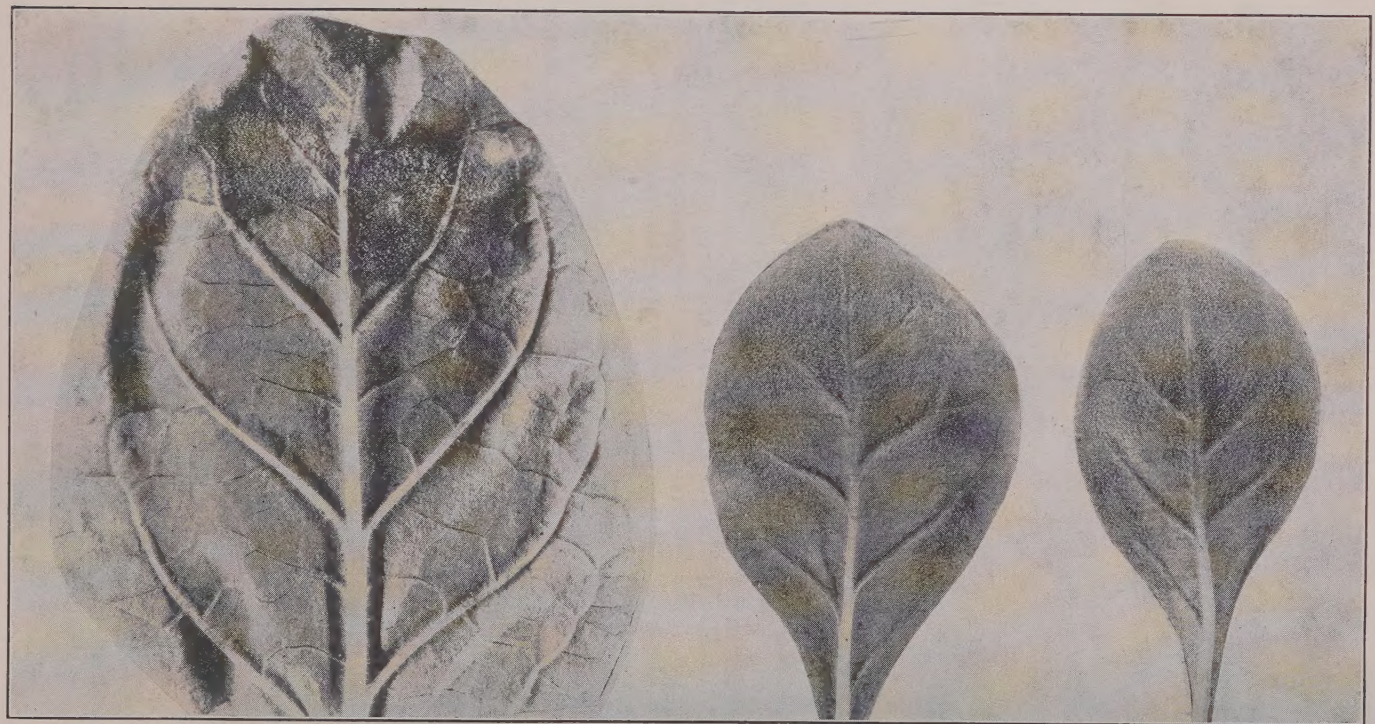

FIGURE 1.—Blue mold symptoms: The cottony growth of fungus on the lower leaf surface. Note that the small leaves from young plants may have the lower surface practically covered, while with large leaves the lesions are more definite and limited. This growth is usually white but may be pale violet, and its presence distinguishes the disease from leaf yellowing caused by malnutrition or frost injury.

characteristic cottony fungus growth on the lower surface (fig. 1). This growth is either white or pale violet in color. There are two common troubles with which blue mold is confused. Yellowed patches of plants sometime appear in a bed because of malnutrition, and frost injury may yellow leaf tips. In neither case, however, is any cottony mold growth to be found.

After the infection has appeared, it usually progresses slowly for several weeks. Then a general outbreak occurs, and the entire bed becomes diseased almost overnight. The severity of this attack will depend on the weather and the age of the plants. Young plants may be killed outright; older ones may be reduced to stem and bud. During this period, also, the roots of affected plants turn brown. The plants in the bed look very sick at this time, but in a few days some of them may begin to recover. The rate of recovery will depend on the severity of the attack and the weather. If many leaves are only partly killed and the weather turns warm, recovery will be very rapid. On the other hand, with continued cool weather, recovery may be very slow. Ultimately, however, practically all the surviving plants recover completely and make a normal growth when transplanted to the field. Also, no matter how mild or severe the attack, once recovery has occurred, the plants are so resistant that serious damage from a second mold attack before the plants are ready to set need not be feared (fig. 2).

LIFE HISTORY OF THE DISEASE

Blue mold is caused by a fungus (*Peronospora tabacina* Adam). The cottony fungus growth seen on the lower leaf surfaces is made up of sporophores and spores (fig. 3), which correspond to the trunk, branches, and fruit of a tree. The mycelium, from which the sporophores arise, grows through the tissues of the leaf and secures its food from these. This fungus can only survive as long as the leaf remains alive; as soon as the leaf dies, new sporophores and spores stop appearing on the surface. Leaves may be seen with a dead brown area surrounded by a diseased yellow area, which is covered with fresh sporulation.

The disease is spread by means of the spores which are so light as to be readily carried by air currents. At times the spores are carried long distances, as much as 50 to 75 miles or more; hence no seedbed in an affected area is likely to escape the disease, although some will be infected sooner than others. Spores that chance to fall on tobacco leaves will germinate, if moisture is present, and grow into the leaf in a few hours. Once inside, the mycelium continues to grow, the infected area gradually yellows, and in about 7 days the cottony growth develops on the under-leaf surface, indicating that a new crop of spores has been matured. They form in the early morning, and most of them are dead by 9 a. m. A few, however, live longer; under favorable conditions some have remained alive 2 weeks.

The fungus occasionally produces another kind of spore, the resting or oospore. This spore is long-lived and enables the infection to persist in the soil of old seedbeds. It is also possible that in some localities the infection may remain alive in plant tissues and, if these survive the winter, be carried over into the next season.

FIGURE 2.—Comparative susceptibility to blue mold of recovered and freshly infected plants. Both plants were exposed to the same general severe blue mold attack. Plant *A* came from a portion of the seedbed that had been affected 2 weeks earlier and had recovered, while plant *B* was attacked for the first time. Plant *A* was reinfected, as is indicated by the light-colored areas on several leaves, but was practically uninjured, whereas the larger leaves of plant *B* were killed.

RELATION OF WEATHER CONDITIONS

Blue mold is particularly responsive to temperature (fig. 4) and moisture conditions. Since 1931 most beds throughout the flue-cured area have been infected each year, but in only 2 years has the disease been generally destructive. Each of these years a warm winter with frequent cloudy days was followed by an unusually early appearance

of the disease in the plant beds. Consequently, in the future, growers should be warned by this combination of events. During the early spring, with minimum night temperatures between 40° and 50° F., the disease does not develop rapidly. Infected leaves may remain alive some days, producing new spore crops each night, and infection may remain apparently confined to certain limited areas of the plant bed.

The epidemic outbreak, when the entire bed is affected, comes with warmer nights—usually with a minimum temperature of 50° or more, accompanied by fogs or light rains. Heavy rains, for some reason,

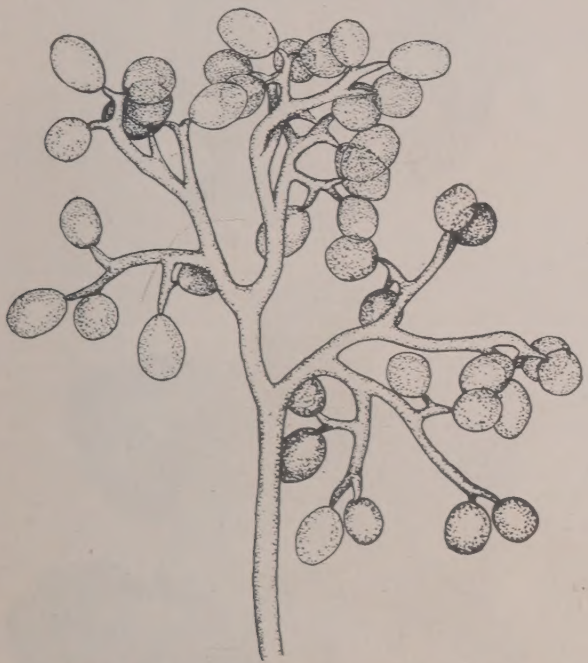

FIGURE 3.—A sporophore bearing spores. The oval spores are very light and are easily carried through the air from leaf to leaf (× about 300). The cottony growth seen on lower leaf surfaces is made up of a mass of these sporophores.

tend to check mold development. However, if favorable temperatures prevail early and infection becomes well distributed, even though cool weather follows, the disease may continue to be very destructive. As the minimum night temperatures have risen to between 65° and 70°, the disease has disappeared. At this temperature, and in fact up to temperatures as high as 75°, the mycelium is very active, but usually the leaf tissues die very quickly and produce few, if any, spores. This automatically brings the activity of the disease to an end.

HOST PLANTS

The blue mold disease is confined to tobacco. Tomatoes, eggplant, and more particularly peppers, when grown in the same bed or very near to tobacco plants, are sometimes infected, and may even be

slightly damaged, but they can hardly be regarded as susceptible. There is a similar-appearing but entirely distinct fungus that attacks collards and cabbage.

FIGURE 4.—Blue mold response to temperature conditions. The plants shown were uniformly infected. Pot *A* was then moved into a warm temperature (70° to 110° F.), and the fungus produced the small white lesions and then died out completely. Pot *B* was moved to a cool temperature (60° to 80° F.), and the fungus continued active.

LOSSES FROM BLUE MOLD

The disease affects the crop in several ways. (1) The disease may kill plants outright. In most beds there are enough plants so that even as much as a 50-percent loss would still leave a fair stand. In 1932 and again in 1937, however, the percentage kill in some localities was so high that an acute shortage of plants resulted. (2) There is the problem of delay in transplanting. Whenever the disease occurs

there is some delay. If the attack is light and the recovery prompt, the delay may be less than a week; if the attack is more severe, there may be a delay of 4 or 5 weeks. Most growers set tobacco "on a season," and if one or more favorable planting times are lost because of mold, this delay may be serious. In addition, if planting is much delayed, the crop may be late, and such crops usually are lacking in yield and quality. (3) There may be a poor stand as a result of transplanting diseased plants. The growers are well aware that plants must recover from the disease before they can be safely set. However, the situation frequently arises that weather and land conditions are favorable for transplanting, but the plants show some disease. Then it is always a question whether to plant and risk a poor stand or not to plant and miss a good season. (4) When considering losses, it should be remembered that because of the mold thousands of growers are now going to the labor and expense of growing 100 square yards of seedbed per field acre, whereas before the mold became prevalent, half this area was considered adequate. This added expense alone is a large item.

CONTROL MEASURES

CULTURAL PRACTICES

As recommendations for control by cultural practices have been put forward many times, they will be stated only briefly here.

Growing Plants in Areas Free From Blue Mold.—This has often been considered, and it is possible in some localities. The Georgia grower can produce plants without fear of serious blue mold attack by going about 250 miles south into Florida. Even as close as the extremely northern part of Florida the disease is much less active than in the southern part of Georgia.

Avoiding Early Infection.—In certain parts of the South, plants may live over in old beds, develop mold very early, and serve as a source of infection for nearby new beds. Also, volunteer seedlings from parent hold-over plants left in old beds may become infected and enable the fungus to get an early start. To prevent this, hold-over plants should be destroyed before they produce seed. It has already been pointed out (p. 3) that the infection may persist in the soil of old seedbeds; if such soil is used a second year and is sown early, the plants may be exposed to an early attack. Lastly, if both early and late beds are sown, it is advisable to separate them, because the early beds develop mold first and may then serve as a source from which abundant infection is spread to nearby late beds.

Growing Plants Ahead of the Disease.—Tobacco growers observed that during the period 1933–36 the mold attack usually came just as plants were almost large enough to set and that some early plants were set out ahead of the disease. In 1937 many growers planted earlier than usual, and to further hasten growth, many used very frequent applications of nitrate. The idea was to get the plants out in advance of the disease and, in any case, to have the plants as large as possible at the time of disease attack. Extra-early sowing, however, did not work out well. In Georgia, plants were much ahead because of early sowing and a warm winter. Yet the disease killed about 80 percent of them. In some localities, both frost and mold damaged the early plantings severely. It would seem that, insofar

as the date of sowing and fertilization is concerned, the best agronomic practices should be followed regardless of blue mold.

Sunny Bed Locations.—It is unquestionably true that mold is more severe in shady beds and in the shady portions of a bed.

Thin or Thick Stands.—The value of thin stands has been frequently mentioned, but close study of many beds has failed to show any gain in blue mold control in thin stands. Some thin stands were reduced to a few scattering plants in 1937, while in thicker stands enough plants survived to give a fair yield.

Removal of Covers.—Covers are generally removed as soon as the weather permits and earlier removal could hardly be recommended, because if covers are removed too early, the plant growth will be stunted. After the disease has developed, removing the covers has little, if any, effect on the mold.

Increased Seedbed Areas.—Reference has already been made to the fact that throughout the flue-cured area growers are planting vastly larger seedbeds. Many expect to get only one or two good pullings, whereas formerly they obtained three or four. Increased seedbed area is unquestionably the most effective cultural method of reducing blue mold loss.

Hastening Recovery With Applications of Nitrate.—After plants have been defoliated by the disease, it is essential that they grow new leaves. Beds may be short of nitrogen at this season and, when this is the case, one or more light applications will aid recovery. Many growers have started making heavy applications of nitrate as soon as the disease appeared; this has frequently resulted in severe plant injury.

Allowing Plants To Recover Before Transplanting.—Experiments and the experience of growers combine to show that once the mold appears, it is not advisable to attempt to hurry plants to the field. Rather, they should be allowed to remain in the bed until the disease attack has passed and recovery is apparent. As soon as new leaves and roots are produced, the plants can be set out safely.

Growers who prefer to depend on cultural practices to combat blue mold should continue to plant very large seedbeds and, after the disease appears, should delay transplanting until the surviving plants have recovered. In regard to bed location, fertilization, rate of sowing, and the handling of covers, while some thought should be given to blue mold, the primary consideration should be the best agronomic recommendations for the area.

HEAT TREATMENTS

Blue mold attacks are limited to the spring because this disease is unable to develop in hot weather. This fact suggested the value of heating the seedbeds. Extensive experimentation has shown that if night temperatures in the usual type of spring beds are raised to between 70° and 90° F., good control of the disease is obtained. Many forms of heat have been used. Electric heating cables laid on the soil surface proved very convenient and effective, but electricity is an expensive source of heat. Kerosene burners, such as are now used to some extent in curing, having probably been the most satisfactory source of heat. The heat and fumes from such burners tend to reduce humidity and harden plants slightly, but this appears to be an ad-

vantage. To use heat treatment, it is necessary to construct tight beds and to provide covers. Glass sash has been the most satisfactory cover. Glass substitutes and heavy cloth have been used but were not so effective. Heat treatment does not appear practicable, however, because it involves too much labor and expense. The cost of heat protection against blue mold is estimated to be at least $60 per 100 square yards of bed.

GAS TREATMENT

Control by gas treatment was developed in Australia. Work in this country was begun in the fall of 1935, and gas treatment proved at once to be highly effective. The original Australian recommendation

FIGURE 5.—Gas treatment for blue mold control. These beds, 9 feet wide and 68 feet long, were provided with tight sides and an overhead frame to support the cloth sheets. The long narrow evaporating pans were hung from the ridge pole and provided an evaporating surface of one-hundredth the bed area. The benzol was poured in with the aid of a funnel and tube.

was to distribute pans throughout the seedbed so as to provide a continuous evaporating surface one-seventy-second of the bed area throughout the night and to enclose the bed with tight cloth covers to hold in the fumes. Under conditions in this country, this treatment has been too strong. Repeated tests have shown that an evaporating surface equal to one-hundredth of the bed area is adequate and that 1 fluid ounce of benzol per square yard of bed area per night is sufficient. When very tight covers have been used, good disease control has been obtained with less than this amount of benzol. The benzol was usually completely evaporated by the time the covers were removed in the morning. Evaporating pans must be well distributed through the bed. Insofar as the authors are aware, the evaporating surface of the individual pans used has been one-half square foot or less.

A variety of covers have been tried, including glass and grades of cloth ranging from the usual tobacco cotton to a closely woven

gasproof cloth.[1] Satisfactory mold control was secured in all cases with heavy muslin and gasproof cloth; but both materials shed most of the rain, and this was a disadvantage. Promising results have been obtained with medium grades of unbleached-muslin sheeting that are rain pervious. Large covers (fig. 5) and small wooden cloth-covered frames have been used, and both have advantages as well as disadvantages. Regardless of type of covering, narrow beds, preferably not more than 9 feet wide, are desirable, and they must be so constructed that there is overhead space for gas circulation. The cloth covering must be well supported or else during heavy rains it will sag, and benzol pans will be overturned and the plants crushed.

The advantage of gas treatment is that it is highly effective, and even after the disease has appeared it is possible to check disease development completely by a few nights' gassing. The disadvantage of the treatment is the labor and expense. Thus, beds must be covered each night and uncovered each morning, and the pans must be cared for. The materials, of which the covering is a major item, cost at least $15 per 100 square yards of bed. Gas treatment for blue mold is a rather recent discovery, and various possible modifications to make it more practicable are being tested.

SPRAYING

After much research, a spray treatment was developed and tested out extensively during 1937. The recommended mixture contains one-half pound of red copper oxide, 1 quart of Lethane spreader, one-half gallon of cottonseed oil, and water to make 50 gallons. It must be applied twice a week. Ordinarily an average of 8 to 12 applications will be sufficient. The spray treatment does not eliminate blue mold, but it has consistently reduced the disease to a point where it does little or no damage. Spraying was highly effective even under the very severe conditions that prevailed in Georgia in 1937 (figs. 6 and 7). It requires no modification of present plant-growing practices and is inexpensive. The average cost of materials per 100 square yards of bed should not exceed $2, and satisfactory sprayers have been purchased for $20 to $25.

Few tobacco growers have had any experience with spraying; hence, in addition to studying the recommendations made here, they would do well to obtain aid, if possible, from local advisers who have had experience. It was thoroughly demonstrated to the satisfaction of many growers during 1937 that there is nothing complicated about spraying. However, to obtain good results, growers must use proper equipment and the right spray (fig. 8) and must carry out the program of applications conscientiously. The recommendations made here have been subjected to careful tests over a period of 3 years, and many variations have been tried and discarded.

EQUIPMENT

The sprayer must be capable of developing good pressure, so that it will deliver an even, finely divided mist. The best small outfit used has been the so-called wheelbarrow or pushcart type (see cover). This outfit, equipped with 50 feet of ⅜-inch hose and a 6-foot rod,

[1] Supplied through the courtesy of the marketing section of the Agricultural Adjustment Administration.

costs between $20 and $25. The tank holds 12 gallons, and 100 square yards of bed can be covered in about 15 minutes. No stock sprayer is equipped at the factory with sufficient hose, unless the length de-

FIGURE 6.—A sprayed bed on a farm near Tifton, Ga. This photograph was taken March 18, 1937, just prior to the first pulling. A total of 7.3 acres of tobacco was set per 100 square yards of bed.

sired is specified in the order. With large beds, 50 feet is none too much. If it is essential that a less expensive sprayer than that described be secured, the double-action bucket pump is recommended,

preferably the type with a small air chamber at the top. Growers with extensive bed areas will find the barrel outfit (fig. 9) most satisfactory. Since this cannot be easily carried between beds, it should be

FIGURE 7.—Unsprayed check bed on farm shown in figure 6. Blue mold killed 84 percent of the plants, and the total set was 1.7 acres per 100 square yards of bed.

equipped with 100 feet of hose and a suitable rod. The outfit illustrated cost about $65 complete and maintained 150 pounds pressure with ease.

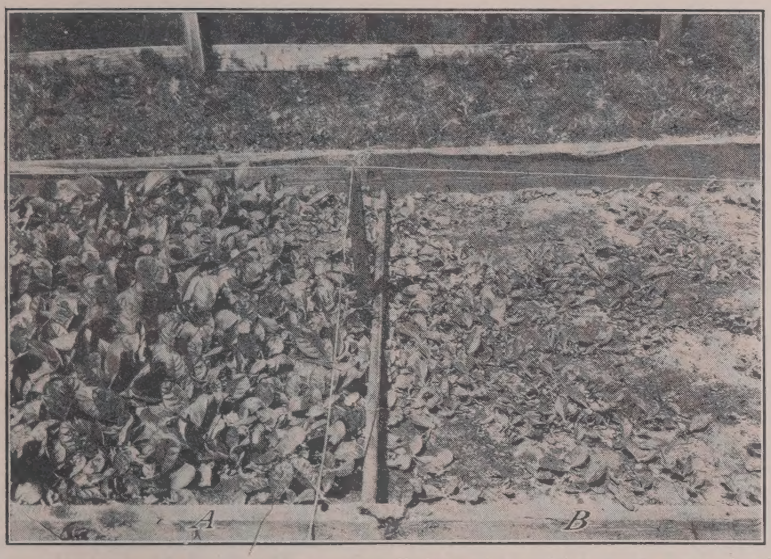

FIGURE 8.—Comparison of effective and ineffective sprays: Plot *A* was sprayed with the recommended copper oxide-cottonseed oil and plot *B* with an ammoniacal copper preparation that has been widely sold as a blue mold remedy. The plants in plot *B* suffered as severe injury from the disease as the unsprayed checks.

FIGURE 9.—Spraying tobacco beds with barrel outfit. Note the extra hose and long rod which make it possible to get around beds and spray in from the sides. Growers with large bed areas will find this type of outfit very efficient and satisfactory.

Other types of barrel outfits, costing as little as $30, have also been used with considerable satisfaction. Power sprayers are excellent, but they are much too expensive for individual use. However, it may

be noted that with a power sprayer, 250 pounds pressure, and four nozzles in line, 1,000 square yards of bed can be sprayed in about 15 minutes.

MATERIALS AND METHODS FOR MIXING

The spray formula recommended is as follows: One-half pound red copper oxide, 1 quart Lethane spreader, one-half gallon cottonseed oil, water to give a total volume of 50 gallons.

The red copper oxide should be fresh and should be finely divided. The presence of dark lumps is a sign of deterioration. The formula given above is based on a copper oxide containing 85 to 90 percent of copper. If the package label gives a lower percentage of copper, the amount used in mixing the spray should be proportionally increased.

The Lethane spreader is a commercial product, which is used to emulsify the oil. This spreader does not readily deteriorate.

Cottonseed oil may be purchased as such or under a number of trade names. The refined oil has been used regularly, but the raw oil has been tested and has given satisfactory results.

Growers are urged to follow the above formula closely. A possible modification is to increase the copper oxide from one-half to three-fourths of a pound for not more than three or four applications, starting as soon as mold is very active. The ½–1–½ formula previously given above is the one for regular use and the only one that should ever be used on small plants.

In mixing the spray it is necessary to emulsify the oil thoroughly and to get the copper powder into water suspension. If a 50-gallon barrel sprayer is to be filled, the procedure is as follows: First, fill the barrel about two-thirds with water. Then place one-half pound of the red copper oxide in a bucket. Measure out 1 quart of Lethane spreader and add a small portion of this to the copper powder, stirring it into a thick paste. Pour the remainder of the spreader into another bucket and add one-half gallon of cottonseed oil and about 1½ gallons of water. Stir the mixture and then produce an emulsion by pumping it into another bucket by means of an inexpensive bucket sprayer. If the pushcart type of sprayer is available, it can be used to emulsify the oil, but merely stirring with a paddle is not adequate. Pour the emulsified oil into the partly filled sprayer. If properly prepared, the mixture will appear milky white and have no drops of free oil on the surface. Now take the bucket with the copper-oxide paste, stir up the paste first with a little water, and finally fill the bucket. Pour this into the barrel and, if some copper oxide remains in the bottom of the bucket, work this up in additional water and pour it into the barrel.

Finally, add enough water to make the 50-gallon volume.

This procedure can be readily adapted to the mixing of any size lot of spray. The prepared spray should be used at once; the agitation incident to moving and pumping will keep the spray thoroughly mixed. If it should stand some time, stir well before using. Do not keep it overnight.

If a cottonseed oil already emulsified and a copper oxide that mixes readily with water should be placed on the market, these products would greatly simplify spray preparation.

SPRAY SCHEDULE

The time to begin spraying is the first important point. Growers should be prepared well in advance and should begin to spray as soon as word is received that mold has made its appearance in the locality. They should not delay until the mold has appeared in their own seedbeds. Applications should be made twice a week, and if rain falls before the spray is dry, the application should be repeated as soon as possible. Spraying should be continued until the plants are set out, or until the disease has made its appearance in the sprayed bed and recovery has occurred. As was noted earlier, sprayed beds frequently suffer a light to moderate attack of mold, but the plants are seldom more than slightly damaged. Such beds require no further spraying after recovery has taken place. Spraying in no way interferes with transplanting, since plants can be pulled and set a half hour after the spray is applied. The number of applications required will range from 6 to 16, depending on how long the mold continues active. On an average, 8 to 12 will be sufficient. Some growers will be delayed and will find their beds infected at the time they are ready to begin spraying. Experimental results show that under such circumstances they may still obtain good protection, provided the disease develops slowly so that there is opportunity for three to four spray applications to be made before a severe mold outbreak occurs. On the other hand, only one or two applications, prior to a general mold attack, have given little or no protection. Thus a late start reduces the margin of safety, and the outcome may be complete failure.

METHODS OF APPLICATION

Plants should receive an even covering of spray at each spraying but should not be drenched. Pressure should be sufficient to deliver the spray as a fine mist. Never attempt to spray when the leaves are wet. Early in the season, when plants are the size of a dime, 2½ to 3 gallons of spray per 100 square yards will be adequate. This amount should be increased until with larger plants from 6 to 9 gallons per 100 square yards will be required. Growers will do well to check on the amounts they are applying. Small plants with the leaves still flat on the ground may be sprayed through the cotton cover, but in this case the amount of spray required will be increased 30 to 40 percent. Spraying through the cloth is only possible when the cover is well above the plants; after the plants are well up from the ground, the cover should be removed during the spraying.

SPRAY INJURY

A certain amount of cupping of leaves, plus a slight flecking and bronzing, is a common occurrence on young plants. This is of no consequence unless it is excessive. Serious injury can be caused by the use of more copper oxide or oil than is recommended, by applying excessive amounts of spray, particularly to young plants, and by failure to emulsify properly the oil or make a good water suspension of the copper oxide.